

Biased attention to threat and anxiety: on taking a developmental approach

Article (Published Version)

Burris, Jessica L, Buss, Kristin, LoBue, Vanessa, Pérez-Edgar, Koraly and Field, Andy P (2019) Biased attention to threat and anxiety: on taking a developmental approach. *Journal of Experimental Psychopathology*, 10 (3). pp. 1-21. ISSN 2043-8087

This version is available from Sussex Research Online: <http://sro.sussex.ac.uk/id/eprint/84542/>

This document is made available in accordance with publisher policies and may differ from the published version or from the version of record. If you wish to cite this item you are advised to consult the publisher's version. Please see the URL above for details on accessing the published version.

Copyright and reuse:

Sussex Research Online is a digital repository of the research output of the University.

Copyright and all moral rights to the version of the paper presented here belong to the individual author(s) and/or other copyright owners. To the extent reasonable and practicable, the material made available in SRO has been checked for eligibility before being made available.

Copies of full text items generally can be reproduced, displayed or performed and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided that the authors, title and full bibliographic details are credited, a hyperlink and/or URL is given for the original metadata page and the content is not changed in any way.

Biased attention to threat and anxiety: On taking a developmental approach

Journal of Experimental Psychopathology
July-September 2019: 1–21
© The Author(s) 2019
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/2043808719860717
journals.sagepub.com/home/jepp



Jessica L. Burris

Rutgers University, USA

Kristin Buss

Pennsylvania State University, USA

Vanessa LoBue

Rutgers University, USA

Koraly Pérez-Edgar

Pennsylvania State University, USA

Andy P. Field

University of Sussex, UK

Abstract

Several researchers have proposed a causal relation between biased attention to threat and the development and maintenance of anxiety disorders in both children and adults. However, despite the widely documented correlation between attention bias to threat and anxiety, developmental research in this domain is limited. In this review, we highlight the importance of taking a developmental approach to studying attention biases to threat and anxiety. First, we discuss how recent developmental work on attention to threat fits into existing theoretical frameworks for the development of anxiety and how attention biases might interact with other risk factors across development. Then we review the developmental literature on attention bias to threat and anxiety and describe how classic methodologies can be modified to study attention biases in even the youngest infants. Finally, we discuss limitations and future directions in this domain, emphasizing the need for future longitudinal research beginning in early infancy that tracks concurrent developments in both biased attention and anxiety. Altogether, we hope that by highlighting the importance of development in the study of attention bias to threat and anxiety, we can provide a road map for how researchers might implement developmental approaches to studying a potential core mechanism in anxiety.

Keywords

anxiety, attention to threat, development, attention bias

Date received: 22 December 2018; accepted: 6 June 2019

Corresponding author:

Jessica L. Burris, Department of Psychology, Rutgers University, Smith Hall, Room 321, 101 Warren Street, Newark, NJ 07102, USA.
Email: Jessica.burris@rutgers.edu



Creative Commons Non Commercial CC BY-NC: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 License (<http://www.creativecommons.org/licenses/by-nc/4.0/>) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (<https://us.sagepub.com/en-us/nam/open-access-at-sage>).

Anxiety's impact across the life span

Clinical anxiety disorders are the most common psychiatric disorders and are estimated to affect up to 20% of the population at some point in development (Bosquet & Egeland, 2006; Gross & Hen, 2004). Anxiety can be impairing across the life span and is a serious mental health phenomenon. Further, anxiety produces acute suffering and increases risk for a range of long-term adverse outcomes (Pine, Helfinstein, Bar-Haim, Nelson, & Fox, 2009). Childhood or adolescent anxiety disorders are also common, with rates in the population between 5% and 10% (Essau, Conradt, & Petermann, 1999; Fergusson, Horwood, & Lynskey, 1993; McGee et al., 1990), and persistent, often leading to twofold to threefold increases in levels of anxiety and depression in adulthood (Beesdo et al., 2007; Cole, Peeke, Martin, Truglio, & Seroczynski, 1998; Copeland, Angold, Shanahan, & Costello, 2014; Last, Perrin, Hersen, & Kazdin, 1996; Orvaschel, Lewinsohn, & Seeley, 1995; Pine, Cohen, Gurley, Brook, & Ma, 1998). High-trait anxious and clinically anxious adults tend to interpret ambiguous information from the environment as threatening, which can lead to avoidance and withdrawal behavior (Beck & Clark, 1988). In addition, anxious individuals more readily acquire fear pairings in learning paradigms (Mineka & Oehlberg, 2008) and are in turn more likely to generalize this fear learning to putatively nonthreatening safety signals (Britton, Lissek, Grillon, Norcross, & Pine, 2011).

Anxiety appears early in life with anxious behaviors at clinical and subclinical levels evident as early as age 3 (Egger & Angold, 2006). Further, aspects of anxiety symptoms including negative affect, social withdrawal, and hypervigilance (Fox, Henderson, Marshall, Nichols, & Ghera, 2005; Guyer, Masten, & Pine, 2013) often begin in infancy. However, the presentation of these symptoms changes across development and into adulthood in predictable ways that can reflect environmental influences (Bosquet & Egeland, 2006) and the development of regulatory processes (Rothbart, Sheese, Rueda, & Posner, 2011). Other biologically based correlates of anxiety are also stable across development. For example, individuals with, or at risk for, anxiety often present with increased heart rates and greater autonomic reactivity over the life span (Pine, 2007). Anxious individuals may also be acutely sensitive to environmental context, monitoring their surroundings for signs of threat or for feedback regarding their place and role in social

engagements (Hadwin & Field, 2010). The behavioral, biological, and social correlates of anxiety are often evident even before the emergence of any disorder. Thus, childhood risk factors for anxiety are thought to morph into the symptoms of the disorder across development (Britton et al., 2011; Pérez-Edgar & Guyer, 2014).

Importantly, a newly emerging literature points to a potential causal relation between biased attention to threat and the development and maintenance of anxiety in both adults and children (Bar-Haim, 2010; Fox, Hane, & Pine, 2007; Von Bockstaele et al., 2014). Biased attention to threat “cause[s] preferential perception of [any] particular category of stimulus based on its relative affective salience” (Todd, Cunningham, Anderson, & Thompson, 2012, p. 365) and can systematically shape an individual's view of the world. For individuals with a specific bias to threat, the downstream consequences are linked to anxiety and social withdrawal. Attention is a key component of cognition and dictates all stages of information processing. The centrality of attention in development grows out of its role as a cognitive mechanism whose core function is to influence the operation of other downstream processing—by choosing the focus of attention for further processing, by maintaining this focus as needed, and by disengaging from the focus of attention when it no longer serves current goals (Posner & Rothbart, 2007). The earliest forms of self-regulation and effortful control are rooted in the ability to disengage, shift gaze, and reorient to a new focus of attention (Rothbart, Posner, & Rosicky, 1994). In this way, attention mechanisms, and biased attention to threat in particular, may play a pivotal role in shaping the individual's experienced environment from the first days of life. At the extreme, these biases can generate and canalize a relatively rigid and inflexible approach to the world.

Given the central role of attention in early processing and regulation, biased attention to threat may be evident from early in infancy and may act as a core mechanism of socioemotional development (Morales, Fu, & Pérez-Edgar, 2016; Pérez-Edgar, Taber-Thomas, Auday, & Morales, 2014). If this view is correct, individual differences in attention, first emerging in infancy, should be associated with diverging trajectories of socioemotional development, and importantly, trajectories for the development of anxiety. Understanding these relations early in development could thus provide avenues for (1) understanding mechanisms that lead to the emergence

of social withdrawal and anxiety and (2) identifying individuals at risk for socioemotional difficulties.

Despite support in the adult literature for a link between attentional bias to threat and anxiety, developmental research in this domain is still limited. Further, there is currently no longitudinal research that investigates the early development of attention bias to threat as a predictor of anxiety. In the current review, we aim to highlight the importance of taking a developmental approach to studying the relation between attention biases and anxiety, outlining how biased attention to threatening stimuli can act as an important factor underlying the etiology and maintenance of anxiety disorders. First, we review developmental research on the relation between biased attention to threat and anxiety. We then describe how recent developmental work can fit into existing (and evolving) theoretical frameworks for the development of anxiety and how attention biases might interact with other risk factors over the course of development. Next, we describe how new adaptations to traditional methods for measuring biased attention to threat can be used to capture patterns of biased attention developmentally, particularly in infant populations. Finally, we conclude by discussing limitations of the current literature and directions for future research.

Altogether, we hope that by describing new research on attention bias to threat and anxiety in infants and children, and the methods that can be used to examine these variables and the relationships between them, we can provide a road map for how future researchers might implement developmental approaches to studying a core mechanism of socioemotional functioning. By highlighting early attention as an underlying mechanism in the emergence and developmental arc of anxiety, we aim to encourage future developmental work that ultimately helps us identify targets for early detection and intervention.

Biased attention to threat and anxiety in early development

Humans' ability to recognize and detect threatening stimuli has been of interest to basic science researchers for decades (see LoBue & Rakison, 2013, for a review). Research has shown that both humans and nonhuman primates rapidly detect the presence of biological or evolutionary threats, such as snakes, spiders, and threatening conspecifics (e.g., angry faces) more quickly than they detect neutral or benign stimuli (LoBue, 2009; LoBue & DeLoache, 2008, 2010;

Ohman et al., 2001). Further, selective attention to snakes, spiders, and angry faces (LoBue, Rakison, & DeLoache, 2010) is evident behaviorally by 4–7 months (de Haan & Nelson, 1998; Kotsoni, de Haan, & Johnson, 2001; LoBue, Buss, Taber-Thomas, & Pérez-Edgar, 2017; Nelson & Dolgin, 1985; Peltola, Yrttiaho, & Leppänen, 2018; Rakison & Derringer, 2008) and in electrophysiology by 4–5 months (Hoehl & Striano, 2008; Striano, Kopp, Grossmann, & Reid, 2006). Similarly, a bias for fear faces emerges between 5 and 11 months of age (Peltola, Hietanen, Forssman, & Leppänen, 2013) in typically developing individuals. Mechanistically, biased attention may act as a rapid, reflexive response that precedes and supports more evaluative processing of environmental events (Todd et al., 2012). Thus, although biased attention to threat has traditionally been studied in typically developing populations, recent investigations into biased attention and its relation to the development of anxiety represent a key advancement. Indeed, if infants preferentially attend to threatening or negative social information in the environment, this information may play a role in shaping their expectations about social situations and, ultimately, their social behavior. Thus, biased attention to threat can act as a domain-general mechanism that overtime may support the emergence of entrenched regulatory patterns of behavior (Morales et al., 2016).

Importantly, biased attention to threat is not necessarily accompanied by signs of fear to the threat cue (LoBue, 2013). Rather, low-level perceptual biases draw attention to a personally salient environmental cue, which in conjunction with maturation and relevant experiences (e.g., social signals from adults) can “tune” filters in the deployment of initial attention and subsequent processing, gradually sculpting attention patterns from infancy onward, impacting memory encoding and behavior enactment (Leppanen & Nelson, 2006; Scerif, 2010). This process may serve as one underlying mechanism leading to biased attention to threat evident in the clinical and temperament literature (Bar-Haim, 2010; Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007; Fox & Pine, 2012). Perceptual biases may have the greatest impact on individuals who are predisposed to high levels of fear and anxiety, such as children who go on to show extreme temperaments marked by fear and risk for anxiety, particularly behavioral inhibition (BI) and dysregulated fear (DF) (Buss & Kiel, 2013; Buss et al., 2013).

Cognitive theories of anxiety already focus on the role of information processing biases in the disorder (Mathews & Macleod, 2002; Rapee & Heimberg, 1997). Laboratory computer-based tasks reflect this assessment as clinically anxious children (Roy et al., 2008; Waters, Henry, Mogg, Bradley, & Pine, 2010; Waters, Mogg, Bradley, & Pine, 2008) and adults (Mathews & MacLeod, 1985) show spontaneous biases to threat stimuli in their environments (see Dudeney, Sharpe, & Hunt, 2015, for a recent meta-analysis of these findings in children). However, the role of biased attention to threat does not appear to have a “clean” linear relation to anxiety. For example, emerging data suggest that along with a bias *toward* threatening stimuli, biases *away* from threatening stimuli are also associated with anxiety (Shechner et al., 2012). Direction may reflect diagnostic boundaries, as distress disorders have shown a significant bias toward threat, whereas children with fear disorders show a bias away from threat (Waters, Bradley, & Mogg, 2014), so some qualification of diagnostic category or criteria might be necessary for comparing data across these studies. For example, in adults exposed to military attack, threat avoidance was associated with proximity to attack and subsequent levels of Post Traumatic Stress Disorder (PTSD) (Bar-Haim et al., 2010; Wald et al., 2011).

These patterns of vigilance and avoidance are also evident in the temperament literature. Morales, Pérez-Edgar, and Buss (2015) found that 5-year-old children characterized for DF as toddlers displayed attentional avoidance of emotion faces (Morales, Pérez-Edgar, & Buss, 2015). However, bias scores were still positively associated with anxiety. Nine- to twelve-year-olds completed two related tasks (dot probe and affective Posner) and the data suggest that children with inconsistent bias patterns were low in anxiety (Morales et al., 2017). Children with stable patterns of attention, either toward—or—away from threat, showed elevated levels of anxiety. There is some evidence that behaviorally inhibited (BI; reviewed below) children show a similar bias toward threat (Pérez-Edgar, Bar-Haim, et al., 2010), which in turn helps sustain a developmental link between early BI and later socioemotional difficulties (Pérez-Edgar et al., 2010, 2011; White, Degnan, et al., 2017).

While there is evidence that adults with clinical levels of anxiety (but not those without) are likely to display biased attention to threat (Bar-Haim et al., 2007), we do not know whether the pattern develops overtime or whether it is present early in

life. As mentioned previously, some studies have shown that biased attention to threat is typical for all children, regardless of anxiety level (Ehrenreich & Gross, 2002; Kindt, Bierman, & Brosschot, 1997; Kindt, Brosschot, & Everaerd, 1997; LoBue, 2009; LoBue & DeLoache, 2010; LoBue & DeLoache, 2008; Morren, Kindt, van den Hout, & van Kasteren, 2003), others suggest that these biases are specific to children with anxiety (Waters et al., 2008), while others provide evidence that the two arguments are not mutually exclusive. For example, Waters, Lipp, and Spence (2004) showed that while anxious 9- to 12-year-old children have a greater bias toward affective stimuli, both anxious and nonselected children showed a specific bias for threatening stimuli. Similarly, LoBue and Pérez-Edgar (2014) reported that while all 5-year-olds demonstrate a bias for both social (angry faces) and nonsocial (snakes) threats, extremely shy children show an elevated bias for social threats specifically when compared to nonshy children.

Given these findings and others (e.g., Price et al., 2016), attention biases for social threats might be relative, with individuals with clinical levels of anxiety demonstrating a *greater* bias when compared to a nonclinical sample. However, most of these studies focus on either adults or children older than the age of 5 years. It may be that biased attention to threat in both anxious and nonanxious individuals is already established by this age. Thus, the question of how these biases develop over the first few years of life and how they relate to behavior is still open, and there is a critical need for longitudinal studies looking at these processes starting in infancy. Studies examining whether attention bias to threat is a concurrent symptom of, or precedes anxiety symptoms longitudinally, starting in early development, are still needed.

Several studies demonstrate that experimentally manipulating biased attention to threat in healthy and anxious children and adults (Bar-Haim et al., 2012; Eldar & Bar-Haim, 2010; Eldar, Ricon, & Bar-Haim, 2008; Eldar et al., 2012; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002; Mathews & MacLeod, 2002; Schmidt, Richey, Buckner, & Timpano, 2009) produces a subsequent change in anxious behavior and stress-related reactivity (Bar-Haim, 2010; Hakamata et al., 2010; Lazarov et al., 2018; Naim, Kivity, Bar-Haim, & Huppert, 2018, but see Cristea, Kok, & Cuijpers, 2015). The findings support the argument that biased attention to threat is as a causal mechanism in the development and

maintenance of anxiety. However, this is a mechanistic argument supporting the potential for causality. While experimental designs can support causality, it remains an assumption that this is the pathway through which biased attention develops or that this is the mechanism at play in the natural development of anxiety (Pérez-Edgar & Hastings, 2018). The degree to which biased attention to threat represents a downstream result of ongoing anxiety or an early-emerging predisposing factor implicated in the risk for anxiety remains unclear. Importantly, we still lack a critical component needed to understand these observed patterns: We do not know the antecedents of these divergent attentional patterns nor the mechanisms leading to vigilance or avoidance.

Developmental research involving infants has demonstrated the existence of biases for various kinds of salient stimuli for decades. Indeed, well-known paradigms like preferential looking and habituation tasks depend on the fact that infants are biased in where they look (Teller, 1979). However, research on infants' biased attention to threat is still quite limited, leaving open the question of when these specific biases develop and how normative biases might shape socioemotional development over the course of the life span. Recently, Burris, Barry-Anwar, and Rivera (2017) showed that a bias toward both negative and positive emotional expressions was normative in a sample of typically developing children aged 9–48 months, implementing similar experimental parameters that have been used to measure attention biases in adolescent and adult populations. Similarly, LoBue, Buss, Taber-Thomas, and Pérez-Edgar (2017) demonstrated that biases for both social (angry faces) and nonsocial (snakes) threats are measurable between the ages of 4 and 24 months in typically developing infants using an eye-tracking methodology. In one of the few studies incorporating anxiety and attention to threat in young children, Dodd et al. (2015) showed that, on an eye-tracking visual paired-comparison task, both anxious and nonanxious 3- to 4-year-old children showed attentional vigilance and longer dwell times to angry faces compared to neutral faces.

Importantly, other work has linked early patterns of attention with the manifestation of later temperament. While the literature linking BI and attention to threat is limited, Pérez-Edgar et al. showed that greater vigilance (less sustained attention) at 9 months was associated with increases in BI from 14 months to 7 years (Pérez-Edgar et al., 2010). Moreover, initial BI levels

predicted social difficulties assessed during an observed social dyad interaction with an unfamiliar peer at age 14 years only when the individual had shown high levels of vigilance as an infant. This work has laid the groundwork for developing new methodologies for studying biased attention to threat in infants as young as 4 months of age.

One major limitation of this work is the open-ended question of whether biased attention to threat exists as a correlate, a risk factor, or simply a symptom of anxiety. These distinctions are blurred throughout the literature, and clarity with this concept should be an important priority for current and future work in this area. The current review presents strong evidence that there is an association between anxiety and attention, but the field currently does not know how or why it develops or the role that attention plays across development. Again, it is important to note that in many studies, there are large portions of the study sample that have anxiety but do not present biased attention to threat, and vice versa. Thus, there is no question that the framework underlying the development of anxiety is complex, and attention contributes only part of that larger framework. However, we do aim to challenge the notion that biased attention to threat is simply a symptom of anxiety, given the developmental framework that is becoming stronger in the literature. A thorough longitudinal investigation into biased attention across early development is needed, utilizing age-appropriate tasks that can identify attention biases for threat reliably in even very young infants.

Implications for theory

Classically, researchers have proposed that biased attention to threat is the result of dedicated brain circuitry activated automatically in the presence of threat (Öhman & Mineka, 2001). From this view, such biases should be normative, present early in development, and stable across individuals. However, the developmental research presented here suggests that such biases might indeed develop and change over the course of the life span. As a result, more recent perspectives on biased attention to threat and its relation to anxiety have placed particular importance on development.

Field and Lester (2010) suggested three potential developmental models of biased attention to threat. The integral bias model suggests that individual factors (e.g., anxiety and temperament) determine the

presence or absence of attentional biases for threat early in development, and such biases should be relatively unchanging across the life span. As such, infants with early signs of negative affect would already show a more pronounced bias to threat relative to infants without this temperamental profile. In contrast, the moderation model suggests that development moderates the expression of an existing bias to threat, such that under certain circumstances (e.g., in children at temperamental risk for anxiety) initial normative biases might be linked to the later emergence of elevated fear and social withdrawal (e.g., LoBue, 2013; Todd et al., 2012). In contrast, normative biases would decrease overtime for typically developing children who are not at heightened risk for anxiety. This model is in line with Kindt et al.'s (Kindt, Bierman, & Brosschot, 1997; Kindt, Van Den Hout, De Jong, & Hoekzema, 2000) findings that all children start with a bias to spiders, but that it increases over time in adolescents experiencing a spider phobia and decreases over time in control participants. Also, findings by Öhman, Flykt, and Esteves (2001) demonstrate that biases for snakes and spiders are normative in all adults, but there is a heightened bias in adults with snake and spider phobias. Finally, the acquisition model suggests that developmental experiences shape the acquisition of biased attention to threat gradually overtime, either in tandem or in subsequent to the emergence of fear and anxiety. In this model, biased attention to threat would act as a symptom of the disorder that has developed.

At the time of their article, Field and Lester (2010) stated that the integral bias model had the least amount of support of the three, and existing developmental literature does not fit precisely into either the moderation or the acquisition model. Morales, Fu, and Pérez-Edgar (2016) built on this work, suggesting that early occurring biases are later moderated by environmental factors, either intrinsic or extrinsic to the child. The main premise of this argument is that children's normative attentional systems are pretuned to aspects of the environment that are likely to signal healthy and appropriate patterns of approach and avoidance. With development, these biases become modulated in an experience-dependent manner. For a subgroup of children who are at heightened risk for psychopathology, biased attention to threat could reinforce disorder risk by supporting atypical interactions with novelty and perceived threat in the environment, which would then cyclically reinforce biased attention (Morales et al., 2016; Pérez-Edgar et al., 2010, 2014).

Many additional theories related to the fine-grained order of attention processing, components, and possible mediating mechanisms are thoroughly reviewed by Cisler and Koster (2010) and Yiend (2010). Empirical support exists for some of these models, although they are not developmental in nature and thus focus more on the specific order and components of attention that are most involved in biased attention to threat.

Whichever of these models is correct, they all imply that important and relevant learning occurs early in life. Thus, to disambiguate these models, additional work is needed on attention biases for threat and their relation to socioemotional behavior in infancy and early childhood. Importantly, the traditional tasks that are typically used to measure attention bias to threat are not developmentally appropriate for use in infant populations, limiting researchers' ability to disambiguate these models. Most of the literature does not allow us to say anything about the preschool years because it primarily relies on reaction time-based tasks. Therefore, we cannot dissociate different theoretical pathways through which attention to threat and anxiety develops. We are also unable to identify the causal connection between these constructs. Thus, it is necessary to create developmentally appropriate modifications to the traditional tasks to allow for the collection of data with infant populations, which can provide great insight into these components of attention and how they develop and change across development.

Methodological issues

To more thoroughly explore the impact biased attention to threat can have on the development of anxiety, developmental researchers are challenged with developing more infant-directed methods to measure biased attention. Here, we discuss traditional methods for measuring biased attention to threat used in the adult literature, and we then explore adjustments that can be applied to make these methods appropriate for use in young populations (for additional information on the traditional uses of these paradigms, see Bar-Haim et al., 2007 and Cisler & Koster, 2010). Importantly, adjustments that can be applied to standard methods to make them appropriate for pediatric populations might also improve the reliability and validity of the tasks for adult populations.

The *Dot-Probe Task* is perhaps the oldest and most well-cited attention bias task (e.g., MacLeod,

Mathews, & Tata, 1986; Mogg & Bradley, 1999; Mogg, Bradley, De Bono, & Painter, 1997; Koster, Crombez, Verschuere, & De Houwer, 2004; Saleminck, van den Hout, & Kindt, 2007; for review, see Bar-Haim et al., 2007) and is theorized to measure biased attention by tracking reaction time to a visual stimulus after the presence of affective information. Many different versions of the task that utilize different types of stimuli exist. One version of the task that utilizes faces presents two faces side by side, usually paired by emotion—neutral–neutral, happy–neutral, and angry–neutral—followed by some type of probe that appears on the same side of one of the faces that preceded the probe (MacLeod et al., 1986). On congruent trials, the probe appears on the same side of the screen as the emotional face and on incongruent trials, the probe follows on the same side as the presentation of the neutral face. Individuals are tasked with indicating (traditionally with a button press) which side of the screen the probe appears. The theory behind the task is that individuals will respond faster to a stimulus that appears in an attended region of their visual perception than an unattended one (Posner, 1980). Attentional biases are calculated using the time to detect the probe on incongruent versus congruent trials. If individuals are faster at detecting probes that appear in the same spatial location as the threatening faces, it indicates that their attentional system was biased towards threat. If the latency to detect the neutral or happy faces is faster than the threatening faces, we can conclude that the individual is avoidant of threat.

The *Emotional Stroop Task* is commonly used to measure the attentional control component of biased attention. The task is a variation of the classic Stroop task which presents color words in varying “ink” colors (Stroop, 1935). In the emotional variant, a word with either a threatening or neutral valence is presented in a color and the participant is asked to report the color of the word rather than the valence or semantic information. An individual is said to demonstrate biased attention to threat whether they are slower to label the color of a threat-related word versus a neutral word (MacLeod, 1991; Williams, Mathews, & MacLeod, 1996).

Another task that investigates biased attention is the traditional *Visual Search Task* (Ohman, Flykt, & Esteves, 2001). Participants are presented with matrices of stimuli containing four or nine photographs from a single category (target absent) or similar matrices containing a single discrepant image

(target present). Participants asked to indicate with a button-press when they have identified the presence or absence of a discrepant category. Using this paradigm, attentional biases are captured when response times are slower to detect discrepant neutral images than discrepant threatening images (Cisler, Bacon, & Williams, 2009). The task has been used with emotional facial expressions, animals, and even words and has shown biased attention to threat in individuals with anxiety (Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005).

Finally, Posner (1980) presented a *Spatial Cueing Task* that has been used and manipulated extensively in the attention bias literature. In the task, a cue appears in one location and is then followed by a target stimulus that is presented either in the same place as the cue (valid cue trial) or in a different spatial location (invalid cue trial). If cues effectively capture attention, responses to the target should be faster in the valid cue trials than in the invalid cue trials. This difference in reaction time is thought to come from the benefit of having the attention system already fixated to the correct place on the screen before the target is presented. The slowing seen in the invalid cue trials reflects the time it takes to disengage attention, shift to the other side of the screen, and fixate the target. This task allows for a more thorough investigation of the attentional mechanisms guiding biased attention, allowing for separation between attentional disengagement, shift, and engagement. Adding affect-relevant motivation or feedback with the typical neutral cues have shown that the basic mechanism is sensitive to state and trait variation including childhood shyness (Pérez-Edgar & Fox, 2005). Fox, Henderson, Rubin, Calkins, and Schmidt (2001) modified the task to have affective cues and saw that a threatening cue caused a faster response relative to neutral valid cue trials. Both affective variations of the traditional task have found that the orienting effect is potentiated in individuals with anxiety (Bar-Haim, Morag, & Glickman, 2011; Ellenbogen & Schwartzman, 2009) or at risk for anxiety (White, McDermott, Degnan, Henderson, & Fox, 2011).

Methodologies appropriate for infants

The aforementioned traditional attention bias tasks cannot be used with infant populations because of their reliance on active motor responses. Thus, the main limitation of the current literature using these

methods is their inability to address early developmental questions related to attention. The research using these tasks tells us nothing about attention and anxiety before early childhood, by which time both attentional biases and anxiety may already be engrained.

In this section, we will detail methodological adaptations to traditional attention tasks to allow for exploration of biased attention to threat in younger populations. We will focus on the aspects of attention that can be specifically targeted using the modified versions of classic tasks, allowing researchers not only to investigate biased attention to threat in younger populations but also to more precisely unpack which components of attention are most critical to the development and maintenance of anxiety. When examining biased attention in infants, Posner's model of attention (Posner, Rothbart, Sheese, & Voelker, 2012) outlines three core areas of functioning that help inform task creation.

First, the alerting (or vigilance) system is tasked with obtaining and maintaining an alert state. Vigilance is subserved by midbrain structures with strong interconnectivity between frontal and parietal regions and is linked to norepinephrine functioning. Increased vigilance is defined "as potentiated neuronal responsiveness (e.g., lower firing thresholds) in sensory systems receiving their input from the amygdala" (Whalen, 1998). We know that temperamentally reactive individuals show heightened amygdala response to salient stimuli (Pérez-Edgar et al., 2007) and that amygdala hyperactivity lowers sensory thresholds (Catani, Jones, Donato, & Ffytche, 2003). Second, the orienting system plays an important role in early self-regulation, as it is evident in the first year of life and is a core tool in the infant's regulatory armament (Ruff & Rothbart, 2001; Rueda, Posner, & Rothbart, 2005). Third is the executive attention system which is called in to resolve conflict among responses, it is linked to prefrontal (including the anterior cingulate cortex (ACC)) activity, and it is closely aligned with dopaminergic functioning. This system reflects the effortful control behaviors researchers observe in older children (Rothbart & Rueda, 2005).

Importantly, Posner, Rothbart, Sheese, and Voelker (2012) proposed that early variations in attention, particularly executive attention, may shape the later emergence of self-regulation abilities, which in turn would shape observed patterns of emotion and behavior (Rothbart et al., 2011). As such, they characterized 6- and 7-month-olds for levels of

anticipatory looking in a visual sequence task and then observed responses to a novel toy and fear-inducing mask, as well as attention and socioemotional behavior at 3 and 4 years. Although they found that increased anticipation was associated with reticence with a novel toy in infancy and more distress to a scary mask (Sheese, Rothbart, Posner, White, & Fraundorf, 2008), infant anticipatory looking showed stronger associations with orienting behavior than with executive attention in preschool (Posner et al., 2012) and the link with affect in preschool was tenuous (Rothbart et al., 2011). Further, they were unable to describe clear developmental trajectories (Sheese et al., 2008). Some of this difficulty may be linked to the specific protocol used. First, anticipatory looking appears to be quite difficult for young infants, with a mean of only 1.58 ($SD = 1.60$) correct anticipations from a mean of 30 trials per infant. Second, the infants were only characterized for temperament/affect using two brief tasks. Third, the task employed affect-neutral stimuli and may not have elicited relevant individual differences in attention deployment.

To address these issues, researchers have recently begun using eye-tracking technology to develop a set of tasks (described below) that capture core components of attention evident in infants, including rapid orienting to threatening stimuli (vigilance), difficulty disengaging from threatening stimuli (overlap), and the impact of threatening stimuli on subsequent orienting (dot probe). Eye tracking can be used across all ages and is ideal for use in infancy as it can draw information from passive viewing (Oakes, 2010, 2012).

Converting a button press response to a comparable eye-tracking metric can be straightforward given that, in certain task contexts, the button press already exists as a proxy for visual processing speed and direction (Brown et al., 2014). Furthermore, fixation latency arguably better captures this type of processing speed than reaction time as it is not embedded in the motor planning and response mechanisms of a button press. Brown et al. (2014) showed that measures of attention bias using traditional reaction time tasks had poor psychometric properties. As a result, altering tasks more suited for adults or older children to measure latency to fixate a stimulus rather than latency to press a button can improve the accuracy of the task (Price et al., 2014, 2015). Previous eye-tracking versions of classic attention tasks such as the dot-probe have shown positive reliability measurements (Armstrong & Olatunji, 2012). In addition, Burris et al. (2017)

recently showed positive split half correlation values across a young age range (9–48 months) of typically developing infants and children completing the dot-probe task using an eye tracker.

Infant dot-probe task. In line with Posner's model, the dot-probe task taps into the central processing demands of the participants' attention system, measuring reaction time to a probe immediately after the presentation of salient information. Recent dot-probe studies with younger, pediatric populations typically modify stimulus presentation of the standard adult task (e.g., time on screen) to match the participants' processing needs (Garner, 2010; In-Albon & Schneider, 2010). The newer infant version of the task is virtually identical to the classic version; however, instead of requiring a button press to indicate on which side the probe appears, we simply measure latency to fixate the probe. Using this new methodology, we have recently published several reports confirming that biased attention to emotionally valenced stimuli is normative between the ages of 4 and 48 months of age (Burris, Barry-Anwar, & Rivera, 2017; LoBue et al., 2017; Pérez-Edgar et al., 2017). Further, we found that for young infants high in negative affect, attending longer to angry faces was associated with slower subsequent fixation to probes. In other words, for infants who show the highest levels of negative affect, looking at threatening faces had the largest impact on subsequent processing (Pérez-Edgar et al., 2017). Thus, these initial findings suggest that early patterns of attention arising from temperamental differences may indeed shape how children respond to their environments from as early as 4 months of age.

Infant vigilance task. Based on Posner's model, several researchers have designed vigilance tasks to assess infants' initial orienting to emotionally valenced stimuli. Using more standard methodologies, researchers have presented infants with several stimuli on a screen and examined where infants look first, and where they look most. For example, LoBue and DeLoache (2010) presented 9- to 12-month-old infants with two images side-by-side on a large screen and measured how quickly infants turned to look at each one. They found that the infants turned their heads more quickly to look at threatening stimuli, including both snakes and angry faces, than nonthreatening stimuli like flowers and happy faces.

More recently with the use of eye-tracking technology, researchers have been able to pinpoint the exact

location and latency of infants' initial orienting responses, making vigilance tasks both easier to administer and more precise. For example, Fu et al. (in Press) recently presented 4- to 24-month-old infants with a center fixation point followed by a threatening or nonthreatening image that appears in one of the four corners of the screen. They measured how long it took infants to first fixate the target image. Preliminary data suggest that the interaction of negative affect and attention control shifts relative biases to emotional and neutral faces over the course of the first 2 years of life (Fu et al., in Press), suggesting that the infant vigilance task can be used to assess infants' initial bias to detect threatening stimuli in the environment.

Infant overlap task. Consistent within Posner's attention framework, researchers have also designed tasks to examine difficulty disengaging from threatening versus nonthreatening stimuli and attentionally shifting to nonthreatening stimuli. In the classic baby overlap task, infants are presented with an image of an affective (happy or angry face) or neutral image. After a short delay, a probe appears to the right or left side of the center image. Researchers measure latency to direct attention away from the center image to fixate the probe. In this task, infants as young as 7 months of age have greater difficulty disengaging from fearful faces when compared to happy and neutral faces (Peltola, Leppänen, Palokangas, & Hietanen, 2008; Peltola, Leppänen, Vogel-Farley, Hietanen, & Nelson, 2009). Further, Morales et al. (2017) recently reported that in infants ranging from 4 to 24 months of age, difficulty disengaging from threatening stimuli was related to maternal anxiety, with higher levels of maternal anxiety predicting increased difficulty disengaging from angry, but not happy, faces (Morales et al., 2017b).

Importantly, emerging evidence suggests that biased disengagement patterns like these have implications for later socioemotional development. For example, heightened attention to fearful faces at 7 months predicts attachment security at 14 months, with a smaller bias associated with insecure attachment (Peltola et al., 2015). Thus, the infant overlap task can be a useful tool in measuring how difficulty disengaging from threatening stimuli shapes patterns of both attachment and negative affect starting in infants as young as 4 months of age.

Attention and anxiety in the context of other risk factors

Although we have reviewed strong evidence for the impact of biased attention to threat on individuals with anxiety, attention bias is only one of many factors that are believed to put an individual at risk for developing anxiety. From the idea of multifinality, we know that there are many pathways that can be taken to reach the same developmental end point (Cicchetti & Rogosch, 1996), especially one as complex as anxiety. Not all anxious individuals show biased attention to threat, and not all individuals who do have biased attention to threat present with heightened anxiety levels. There are also factors that may moderate attentional processes, reflecting the interaction of different developmental pathways and highlighting that attentional processes do not operate within a vacuum. Thus, we argue that the emergence of anxiety is dependent on attention mechanisms embedded in a larger context (e.g., individual and environmental risk) that eventually lead to disorder.

A number of factors influence biased attention to threat and the development of anxiety, and thus, are important to consider when studying how biased attention might shape anxiety over the course of development. Given their prominence in the literature, we will focus on developmental findings related to three markers of risk—temperament, biology, and contextual environmental factors. While these factors play a prominent role in the attention bias literature, the degree to which we can disentangle their individual and interacting roles is limited by the reliance on reaction time measures that we have reviewed above. Utilizing the developmentally appropriate adaptations to the above tasks will improve what we can learn about these markers of risk, ensure that we can understand the early impact of these risk factors, and that we can follow the trajectory of that impact through childhood.

Temperamental markers of risk

Perhaps, the most widely studied individual-difference predictor of anxiety development is a BI temperament (Fox & Pine, 2012). Here, we will briefly review the extensive literature linking BI to anxiety and then will highlight the burgeoning literature linking attention to threat and BI, ending with a discussion of the positive impact that nonreaction time measures can have on our understanding of the relation between attention to threat and BI early in

development. An individual who has a behaviorally inhibited temperamental style usually presents as being highly reactive, socially inhibited, and is sensitive to novelty (Degnan & Fox, 2007). High negative reactivity measured early in infancy (at 4 months) is predictive of BI in toddlerhood (Fox, Henderson, Rubin, Calkins, & Schmidt, 2001). A behaviorally inhibited temperament is usually identified early in development using an empirically standardized behavioral battery (Degnan & Fox, 2007).

While a direct one-to-one link between reactivity in infancy, BI in childhood, and later anxiety is elusive, Prior, Smart, Sanson, and Oberklaid (2000) reported a modest link between early BI and anxiety disorder diagnoses in adolescence. However, the authors were careful to point out that most infants who were behaviorally inhibited did not develop clinical anxiety disorders. BI itself presents behavioral, cognitive, and biological characteristics that are similar to those seen in anxiety (Clauss & Blackford, 2012; Degnan & Fox, 2007; Pérez-Edgar & Guyer, 2014). Longitudinal studies have shown infants with BI are at an increased risk for exhibiting anxiety by mid-adolescence (Chronis-Tuscano et al., 2009; Kagan, Snidman, McManis, & Woodward, 2001). White et al. (2017), for example, one of the few studies with longitudinal data on the link between attention to threat and anxiety in young children, showed an interaction between attention to threat, temperament, and anxiety at age 7, but no relation at age 5. In a related study, Nozadi et al. (2016) found that attention to threat at age 5 moderated the link between temperament in toddlerhood and anxiety at age 10; in other words, temperament predicted anxiety only for children who showed attentional biases toward threat. Further, in a large-scale meta-analysis, Clauss and Blackford (2012) concluded that BI is one of the most prominent risk factors for developing anxiety and social anxiety specifically. Even when anxiety levels do not meet clinical cut-offs, subclinical levels of anxiety (a variable rarely reported) can still be impairing and present their own challenges to adaptive functioning (Gladstone et al., 2005).

While the literature describes the developmental links between BI and anxiety, recent work is beginning to highlight the mechanisms that support the trajectory between early behavioral inhibition and later anxiety. Here, we highlight the role that biased attention to threat may play in this relation. Adolescents characterized as high in BI as toddlers and in early childhood exhibit a larger bias to angry faces on

the dot-probe task compared to adolescents who were low in BI as toddlers (Bar-Haim et al., 2010; Pérez-Edgar et al., 2010, 2014). Field (2006) showed that BI in early childhood facilitates biased attention to threatening stimuli. However, few studies have shown a direct relation between BI and attention to threat (at least in the traditional reaction time version of the dot-probe task). Rather, much of the data support attention as a moderator of risk. Pérez-Edgar and colleagues showed that biased attention to threat moderated the link between BI in infancy and social withdrawal in adolescence (2010) and at age 5 (2011). In particular, the link between patterns of BI in early childhood and later social withdrawal is only evident in children who also show a bias for threat. Further, Morales et al. (2017) showed that convergence in affective bias patterns across multiple tasks was only evident among behaviorally inhibited children. These studies provide support for the impact that BI can have on anxiety development, and importantly for the current review, the key role that biased attention to threat plays in this relation across development.

Given that much of the work linking BI to attention to threat has been done using the traditional reaction time version of the dot-probe task, we have little information linking concurrent BI and attention bias to threat early in development. Utilizing nonreaction time measures, like the eye-tracking version of the dot-probe task will allow us to better understand the early relation between these factors and to better track their interactions across early childhood.

Biological markers of risk

Biological factors also act as markers of risk for anxiety. The anterior regions of both hemispheres may be lateralized for the behavioral/motivational systems involved in approach and withdrawal behaviors (Davidson, 1988; Fox, 1991). For example, Taber-Thomas et al. (in Press) presents data in 9- to 12-year-old children suggesting that EEG asymmetry patterns reflect functional connectivity patterns in frontolimbic networks. Right frontal electroencephalogram (EEG) asymmetry has been associated with negative affect, behavioral withdrawal, anxiety, and depression in children and adults (Harmon-Jones, Gable, & Peterson, 2010), and increased right frontal EEG asymmetry in response to stress is associated with biased attention to threat in adults (Pérez-Edgar, Kujawa, Nelson, Cole, & Zapp, 2013). A similar pattern is evident in infants at risk for BI (Calkins,

Fox, & Marshall, 1996) and among young children with stable high BI across childhood (Fox et al., 2001). Finally, the presence of right frontal EEG asymmetry increases the likelihood that BI children will go on to exhibit poor social behavior (Henderson, Fox, & Rubin, 2001).

It is important to point out that in addition to evidence for the role of right frontal asymmetry as a biomarker for risk, there is other evidence that shows inconsistencies in the association between frontal asymmetry and socioemotional profiles. For example, Harrewijn, Van der Molen, and Westenberg (2016) showed no evidence of right frontal asymmetry in adults high in social anxiety compared to low socially anxious adults. Further, other studies have found no difference in frontal asymmetry patterns in groups of participants who demonstrate social dysfunction (Beaton et al., 2008; Davidson, Marshall, Tomarken, & Henriques, 2000). While the literature remains mixed, right frontal asymmetry continues to be investigated as a potential neurophysiological marker for anxiety risk.

Besides prefrontal asymmetry, theory and research also point to the dysregulation of physiological systems in children with internalizing (e.g., anxiety) disorders (Bauer, Quas, & Boyce, 2002). Measures of parasympathetic activity and reactivity are associated with early temperament and the later emergence of anxiety (Fox, Henderson, Pérez-Edgar, & White, 2008) and play an important role in physiological regulation of stress (Porges, 2007). One physiological measure central to this discussion is respiratory sinus arrhythmia (RSA), a variable that is associated with respiration and heart rate. Low baseline levels of RSA and/or failure to regulate RSA (i.e., suppress RSA to task demands) have been associated with emotion regulation difficulty (Buss, Hill Goldsmith, & Davidson, 2005), trajectories of increased social wariness (Hastings, Kahle, & Nuselovici, 2014), and anxiety symptoms (Licht, De Geus, Van Dyck, & Penninx, 2009). In recent work, toddlers showing a DF profile (high fear in low threat contexts) also show a dynamic pattern of RSA across 10 tasks consistent with poor regulation (Buss, Davis, Ram, & Coccia, 2018). Specifically, temperamentally fearful children showed elevated and stably high RSA. Importantly, this pattern of RSA “augmentation” was associated with greater fear reactivity during the tasks as well as maternal report of social inhibition and anxiety symptoms consistently 1–2 years later.

While biological factors such as RSA and EEG asymmetry are both implicated in anxiety, further research is needed to incorporate affective attentional biases to models that include these biological factors. For example, Field and Price-Evans (2009) reported that BI moderates heart rate responses following fear learning, demonstrating a link between temperamental profiles, biological factors and threat-related processing. Further, Vallorani, Thai, et al. (under review) showed that biased attention to threat is linked to social anxiety symptoms only in children who are high in BI and who also exhibit right frontal EEG asymmetry. While this handful of studies highlights the potential direct or moderating role that biological factors can play in the development of attention biases, the evidence is still sparse, and further investigations are needed.

Interestingly, gender differences in biased attention to threat are not prominent in the literature. Sass et al. (2010) investigated biased attention to threat in anxiety and showed that there are no robust predictable differences across studies based only on gender. It is very well documented that women present with higher rates of anxiety (both clinical and subclinical levels) (Craske, 2003; Lewinsohn, Gotlib, Lewinsohn, Seeley, & Allen, 1998; McLean, Asnaani, Litz, & Hofmann, 2011; Pigott, 1999). Gender has also been shown to modulate the activation patterns of the amygdala, a brain structure important to both anxiety and biased attention (Kilpatrick et al., 2006). Yet, very little evidence exists in the attention bias literature to support the idea that these basic gender differences translate to differing patterns of attention, although many studies do not report analyses split by gender. This is an area of the literature that needs greater investigation.

Environmental and contextual moderators of risk

In addition to individual, endogenous characteristics, socioemotional development can be shaped by the environmental context in which the child is embedded. Indeed, environmental factors can impact anxiety symptoms directly and influence biased attention to threat. For the young child, the environment is shaped, dominated, and filtered by the primary caregiver (Leppanen & Nelson, 2009). Thus, personal (biased attention, anxiety, depression) and psychosocial stressors (e.g., environmental threat) may impact how the parent interacts with the child and vice versa. Parental behaviors, in turn, shape the child's

experienced environment. In this way, parental attention patterns, psychopathology, and psychosocial stress may influence how infants come to view and approach the world. Children of abusive parents, for example, overperceive the presence of anger in ambiguous facial expressions (Pollak & Kistler, 2002), and in some experimental situations demonstrate a bias *away* from threatening/angry faces (Pine et al., 2005) while in others have shown a bias *toward* threatening/angry faces (Briggs-Gowan et al., 2015).

The link between biased attention to threat and anxiety is also impacted by environmental and contextual factors. Briggs-Gowan et al. (2015) showed that exposure to familial violence significantly predicted anxiety and trauma in young children. Further, Morales et al. (2017b) utilized an eye-tracking task to show that attention bias to threatening, but not happy stimuli, in 4- to 24-month-old infants was positively linked to maternal anxiety levels, providing support for the link between attentional patterns and environmental and genetic risk factors for anxiety. Indeed, Vallorani, Fu, et al. (under review) has found that patterns of biased attention to threat across tasks in infancy are associated with temperament and age only in the context of high maternal anxiety. However, to date, there is no research on how biased attention to threat in parents, parent psychopathology, and parental psychosocial stress together affect the developing biases of infants. The existing findings strongly suggest that environmental and contextual factors may shape the development of early patterns of attention and their link to anxiety development.

Limitations and future directions

The research reviewed here demonstrates that individual differences in biased attention to threat, first emerging in infancy, are likely associated with diverging trajectories of socioemotional development, and in particular, the development of anxiety. The literature is still in its infancy, and further work is needed, but there is emerging evidence that early identification of patterns of biased attention may help unpack the nuanced role that attention might play in the etiology and maintenance of anxiety development. This area of research would thus open the door to promising avenues of cognitive treatment options for anxiety.

In recent years, biased attention to threat has been targeted by an intervention called Attention Bias Modification (ABM) training (Amir, Beard, Burns, & Bomyea, 2009; Bar-Haim, 2010; Hakamata et al.,

2010). ABM treatment involves systematically training individuals who show biased attention to threat to either attend more toward positive or neutral stimuli. Commonly, trials consist of treatment sessions using a modified dot-probe task in which the probe only appears on the side of the screen where the happy or neutral face appears so that the attentional system will be implicitly trained to focus attention away from threatening faces (for review, see Bar-Haim, 2010). Another commonly used version of this treatment is to use a modified visual search or vigilance task in which patients are trained to search for happy faces or positive stimuli in an array of negative faces (Dandeneau, Baldwin, Baccus, Sakellaropoulou, & Pruessner, 2007; Waters et al., 2010). Several recent large-scale meta-analyses suggest that ABM is a potentially promising new technique for reducing anxiety (e.g., Bar-Haim, 2010). Although related work with children and adolescents is not currently reporting strong effects of the interventions (see Cristea, Mogoase, David, & Cuijpers, 2015, for a review), understanding the developmental relationship between attention bias to threat and anxiety could lead to recommendations for when and how ABM might be most effective in child populations.

Future research should also examine attention biases for threat and how they relate to developing cognitive biases that are also commonly associated with anxiety. As mentioned previously, high-trait anxious and clinically anxious individuals tend to interpret ambiguous information from the environment as threatening, which can lead to avoidance and withdrawal behavior (Beck & Clark, 1988). A recent meta-analysis of interpretation biases in children and adolescents confirms the relation between anxiety and a tendency to interpret novel information as negative (Stuijzand, Creswell, Field, Pearcey, & Dodd, 2018). Importantly, this meta-analysis reports an increasingly strong association between anxiety and interpretation bias with age, suggesting significant room for developmental change over time. However, there is no research to date examining interpretation biases in children younger than preschool age, and most studies in this domain focus on children who are between the ages of 8 and 12. Further, there is no research on the developing relation between interpretation bias and attention biases for threat over the course of development. New methodologies, like ERP, may need to be implemented to disentangle whether an interpretation bias is a strong underlying factor of attention biases for threat. This area of research could be a fruitful

domain for unpacking the causal relations between these biases and anxiety overtime.

Relatedly, although the reviewed literature on biased attention to threat presents growing evidence for the relation between biased attention and the development of anxiety, much work is still to be done to clarify the precise role that attention plays. We do not find a one-to-one relation between biased attention to threat and anxiety, given that, much like other risk factors for anxiety, many studies show that only a portion of individuals with anxiety present with attention that is biased toward threat. We cannot currently measure biased attention at a single time point in development and select those individuals as being at risk for, or suffering from anxiety. However, current research, building on the reviewed work, shows great promise toward enhancing the field's understanding of how attention fits into the broader framework of risk factors for anxiety. Additional research is needed to create a more comprehensive model of the different factors that contribute to the development of anxiety and to the complex interplay between them. With additional research into the role that attention toward threat plays in the broader model of anxiety, especially from a developmental perspective, we will be in a better position to understand the role that biased attention can play as a risk factor or marker for early intervention. Finally, although this is a promising area for future work, to date, the literature cannot directly provide the data needed to demonstrate whether biased attention to threat plays a causal role in the development of childhood anxiety, as it has primarily focused on older children and adults when examining the relation between attention, affect, and socioemotional functioning. Further, previous research has generally involved single-session, cross-sectional designs focusing on individuals already presenting with clear signs of clinical anxiety or distress (Bar-Haim et al., 2007; Pergamin-Hight, Naim, Bakermans-Kranenburg, van IJzendoorn, & Bar-Haim, 2015). Indeed, our own prior work suffers from these limitations as well (Morales et al., 2017; Pérez-Edgar et al., 2010; White et al., 2017), focusing on children already displaying clear, stable patterns of extreme fearful temperament. Thus, future work that employs multimethod, longitudinal designs beginning at an early age is still needed. The methods outlined earlier allow for future investigations to begin as early as 4 months of age and suggest that endogenous (biological) and contextual (parental characteristics and environment) markers of risk might be also useful in

detecting and explaining patterns of change. Although to date few studies have deployed such systematic, multilevel measures of functioning and risk in a single sample, previous work and new methodological advances in infant eye-tracking have set the stage for future longitudinal data collection that is needed to properly address open questions related to the link between biased attention to threat and the development of psychopathology.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The manuscript was supported by grants from the National Institute of Mental Health to Dr. Koraly Pérez-Edgar (R21-MH103627), and to Drs. Koraly Pérez-Edgar, Kristin Buss, and Vanessa LoBue (R01-MH109692).

ORCID iD

Jessica L. Burris  <https://orcid.org/0000-0002-9170-0701>

References

- Amir, N., Beard, C., Burns, M., & Bomyea, J. (2009). Attention modification program in individuals with generalized anxiety disorder. *Journal of Abnormal Psychology, 118*, 28.
- Armstrong, T., & Olatunji, B. O. (2012). Eye-tracking of attention in the affective disorders: A meta-analytic review and synthesis. *Clinical Psychology Review, 32*, 704–723.
- Bar-Haim, Y. (2010). Research review: Attention bias modification (ABM): A novel treatment for anxiety disorders. *Journal of Child Psychology and Psychiatry, 51*, 859–870.
- Bar-Haim, Y., Holoshitz, Y., Eldar, S., Frenkel, T. I., Muller, D., Charney, D. S., . . . Wald, I. (2010). Life-threatening danger and suppression of attention bias to threat. *American Journal of Psychiatry, 167*, 694–698.
- Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van Ijzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin, 133*, 1–24.
- Bar-Haim, Y., Morag, I., & Glickman, S. (2011). Training anxious children to disengage attention from threat: A randomized controlled trial. *Journal of Child Psychology and Psychiatry, 52*, 861–869.
- Bauer, A. M., Quas, J. A., & Boyce, W. T. (2002). Associations between physiological reactivity and children's behavior: Advantages of a multisystem approach. *Journal of Developmental & Behavioral Pediatrics, 23*, 102–113.
- Beaton, E. A., Schmidt, L. A., Ashbaugh, A. R., Santesso, D. L., Antony, M. M., & McCabe, R. E. (2008). Resting and reactive frontal brain electrical activity (EEG) among a non-clinical sample of socially anxious adults: Does concurrent depressive mood matter? *Neuropsychiatric Disease and Treatment, 4*, 187–192.
- Beck, A. T., & Clark, D. A. (1988). Anxiety and depression: An information processing perspective. *Anxiety Research, 1*, 23–36.
- Beesdo, K., Bittner, A., Pine, D. S., Stein, M. B., Höfler, M., Lieb, R., & Wittchen, H. U. (2007). Incidence of social anxiety disorder and the consistent risk for secondary depression in the first three decades of life. *Archives of General Psychiatry, 64*, 903–912.
- Bosquet, M., & Egeland, B. (2006). The development and maintenance of anxiety symptoms from infancy through adolescence in a longitudinal sample. *Development and Psychopathology, 18*, 517–550.
- Briggs-Gowan, M. J., Pollak, S. D., Grasso, D., Voss, J., Mian, N. D., Zobel, E., . . . Pine, D. S. (2015). Attention bias and anxiety in young children exposed to family violence. *Journal of Child Psychology and Psychiatry, 56*, 1194–1201.
- Britton, J. C., Lissek, S., Grillon, C., Norcross, M. A., & Pine, D. S. (2011). Development of anxiety: The role of threat appraisal and fear learning. *Depression and Anxiety, 28*, 5–17.
- Brown, H. M., Eley, T. C., Broeren, S., MacLeod, C., Rinck, M., Hadwin, J. A., & Lester, K. J. (2014). Psychometric properties of reaction time based experimental paradigms measuring anxiety-related information-processing biases in children. *Journal of Anxiety Disorders, 28*, 97–107.
- Burris, J. L., Barry-Anwar, R. A., & Rivera, S. M. (2017). An eye-tracking investigation of attentional biases towards affect in young children. *Developmental Psychology, 53*, 1418.
- Buss, K. A., Davis, E. L., Kiel, E. J., Brooker, R. J., Beekman, C., & Early, M. C. (2013). Dysregulated fear predicts social wariness and social anxiety symptoms during kindergarten. *Journal of Clinical Child & Adolescent Psychology, 42*, 603–616.
- Buss, K. A., Davis, E. L., Ram, N., & Coccia, M. (2018). Dysregulated fear, social inhibition, and respiratory sinus arrhythmia: A replication and extension. *Child Development, 89*, e214–e228. doi:10.1111/cdev.12774

- Buss, K. A., Hill Goldsmith, H., & Davidson, R. J. (2005). Cardiac reactivity is associated with changes in negative emotion in 24-month-olds. *Developmental Psychobiology*, 46, 118–132.
- Buss, K. A., & Kiel, E. J. (2013). Temperamental risk factors for pediatric anxiety disorders. In R. A. Vasa & A. K. Roy (Eds.), *Pediatric anxiety disorders* (pp. 47–68). New York, NY: Springer.
- Calkins, S. D., Fox, N. A., & Marshall, T. R. (1996). Behavioral and physiological antecedents of inhibited and uninhibited behavior. *Child Development*, 67, 523–540.
- Catani, M., Jones, D. K., Donato, R., & Ffytche, D. H. (2003). Occipito-temporal connections in the human brain. *Brain*, 126, 2093–2107.
- Chronis-Tuscano, A., Degnan, K. A., Pine, D. S., Pérez-Edgar, K., Henderson, H. A., Diaz, Y., . . . Fox, N. A. (2009). Stable early maternal report of behavioral inhibition predicts lifetime social anxiety disorder in adolescence. *Journal of the American Academy of Child & Adolescent Psychiatry*, 48, 928–935.
- Cicchetti, D., & Rogosch, F. A. (1996). Equifinality and multifinality in developmental psychopathology. *Development and Psychopathology*, 8, 597–600.
- Cisler, J. M., Bacon, A. K., & Williams, N. L. (2009). Phenomenological characteristics of attentional biases towards threat: A critical review. *Cognitive Therapy and Research*, 33, 221–234.
- Cisler, J. M., & Koster, E. H. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review*, 30, 203–216.
- Clauss, J. A., & Blackford, J. U. (2012). Behavioral inhibition and risk for developing social anxiety disorder: A meta-analytic study. *Journal of the American Academy of Child & Adolescent Psychiatry*, 51, 1066–1075.
- Cole, D. A., Peeke, L. G., Martin, J. M., Truglio, R., & Seroczynski, A. D. (1998). A longitudinal look at the relation between depression and anxiety in children and adolescents. *Journal of Consulting and Clinical Psychology*, 66, 451.
- Copeland, W. E., Angold, A., Shanahan, L., & Costello, E. J. (2014). Longitudinal patterns of anxiety from childhood to adulthood: The Great Smoky mountains study. *Journal of the American Academy of Child & Adolescent Psychiatry*, 53, 21–33.
- Craske, M. G. (2003). *Origins of phobias and anxiety disorders: Why more women than men?* Oxon, UK: Elsevier.
- Cristea, I. A., Kok, R. N., & Cuijpers, P. (2015). Efficacy of cognitive bias modification interventions in anxiety and depression: Meta-analysis. *The British Journal of Psychiatry*, 206, 7–16.
- Cristea, I. A., Mogoase, C., David, D., & Cuijpers, P. (2015). Practitioner review: Cognitive bias modification for mental health problems in children and adolescents: A meta-analysis. *Journal of Child Psychology and Psychiatry*, 56, 723–734.
- Dandeneau, S. D., Baldwin, M. W., Baccus, J. R., Sakellariopoulou, M., & Pruessner, J. C. (2007). Cutting stress off at the pass: Reducing vigilance and responsiveness to social threat by manipulating attention. *Journal of Personality and Social Psychology*, 93, 651–666.
- Davidson, R. J. (1988). EEG measures of cerebral asymmetry: Conceptual and methodological issues. *International Journal of Neuroscience*, 39, 71–89.
- Davidson, R. J., Marshall, J. R., Tomarken, A. J., & Henriques, J. B. (2000). While a phobic waits: Regional brain electrical and autonomic activity in social phobics during anticipation of public speaking. *Biological Psychiatry*, 47, 85–95.
- Degnan, K. A., & Fox, N. A. (2007). Behavioral inhibition and anxiety disorders: Multiple levels of a resilience process. *Development and Psychopathology*, 19, 729–746.
- De Haan, M., & Nelson, C. A. (1998). Discrimination and categorization of facial expressions of emotion during infancy. In A. Slater (Ed.), *Perceptual development: Visual auditory, and speech perception in infancy* (pp. 247–286). London UK: University College London Press.
- Dodd, H. F., Hudson, J. L., Williams, T., Morris, T., Lazarus, R. S., & Byrow, Y. (2015). Anxiety and attentional bias in preschool-aged children: An eyetracking study. *Journal of Abnormal Child Psychology*, 43, 1055–1065.
- Dudeney, J., Sharpe, L., & Hunt, C. (2015). Attentional bias towards threatening stimuli in children with anxiety: A meta-analysis. *Clinical Psychology Review*, 40, 66–75.
- Egger, H. L., & Angold, A. (2006). Common emotional and behavioral disorders in preschool children: Presentation, nosology, and epidemiology. *Journal of Child Psychology and Psychiatry*, 47, 313–337.
- Ehrenreich, J. T., & Gross, A. M. (2002). Biased attentional behavior in childhood anxiety. A review of theory and current empirical investigation. *Clinical Psychology Review*, 22, 991–1008.
- Eldar, S., Apter, A., Lotan, D., Pérez-Edgar, K., Naim, R., Fox, N. A., & Bar-Haim, Y. (2012). Attention bias modification in clinically anxious children: A randomized control trial. *American Journal of Psychiatry*, 169, 213–222.
- Eldar, S., & Bar-Haim, Y. (2010). Neural plasticity in response to attention training in anxiety. *Psychological Medicine*, 40, 667–677.

- Eldar, S., Ricon, T., & Bar-Haim, Y. (2008). Plasticity in attention: Implications for stress response in children. *Behaviour Research and Therapy*, 46, 450–461.
- Ellenbogen, M. A., & Schwartzman, A. E. (2009). Selective attention and avoidance on a pictorial cueing task during stress in clinically anxious and depressed participants. *Behaviour Research and Therapy*, 47, 128–138.
- Essau, C. A., Conradt, J., & Petermann, F. (1999). Frequency and comorbidity of social phobia and social fears in adolescents. *Behaviour Research and Therapy*, 37, 831–843.
- Fergusson, D. M., Horwood, L. J., & Lynskey, M. T. (1993). Prevalence and comorbidity of DSM-III-R diagnoses in a birth cohort of 15 year olds. *Journal of the American Academy of Child & Adolescent Psychiatry*, 32, 1127–1134.
- Field, A. P. (2006). The behavioral inhibition system and the verbal information pathway to children's fears. *Journal of Abnormal Psychology*, 115, 742–752.
- Field, A. P., & Lester, K. J. (2010). Is there room for 'development' in developmental models of information processing biases to threat in children and adolescents? *Clinical Child and Family Psychology Review*, 13, 315–332.
- Field, A. P., & Price-Evans, K. (2009). Temperament moderates the effect of the verbal threat information pathway on children's heart rate responses to novel animals. *Behaviour Research and Therapy*, 47, 431–436.
- Fox, N. A. (1991). If it's not left, it's right: Electroencephalograph asymmetry and the development of emotion. *American Psychologist*, 46, 863.
- Fox, N. A., Hane, A. A., & Pine, D. S. (2007). Plasticity for affective neurocircuitry: How the environment affects gene expression. *Current Directions in Psychological Science*, 16, 1–5.
- Fox, N. A., Henderson, H. A., Marshall, P. J., Nichols, K. E., & Ghera, M. M. (2005). Behavioral inhibition: Linking biology and behavior within a developmental framework. *Annual Review of Psychology*, 56, 235–262.
- Fox, N. A., Henderson, H. A., Pérez-Edgar, K., & White, L. K. (2008). The biology of temperament: An integrative approach. In C. Nelson & M. Luciana (Eds.), *The handbook of developmental cognitive neuroscience* (pp. 839–854). Cambridge, MA: MIT Press.
- Fox, N. A., Henderson, H. A., Rubin, K. H., Calkins, S. D., & Schmidt, L. A. (2001). Continuity and discontinuity of behavioral inhibition and exuberance: Psychophysiological and behavioral influences across the first four years of life. *Child Development*, 72, 1–21.
- Fox, N. A., & Pine, D. S. (2012). Temperament and the emergence of anxiety disorders. *Journal of the American Academy of Child and Adolescent Psychiatry*, 51, 125.
- Fu, X., Morales, S., Brown, K., Taber-Thomas, B., Lobue, V., Buss, K., & Pérez-Edgar, K. (In Press). Temperament moderates developmental changes in vigilance to emotional faces in infants: Evidence from an eye-tracking study.
- Garner, M. (2010). Assessment of attentional bias using the dot-probe task in anxious children and adolescents. In J. Hadwin & A. P. Field (Eds.), *Information processing biases and anxiety: A developmental perspective* (pp. 77–108). Chichester, UK: Wiley-Blackwell.
- Gladstone, G. L., Parker, G. B., Mitchell, P. B., Wilhelm, K. A., & Malhi, G. S. (2005). Relationship between self-reported childhood behavioral inhibition and lifetime anxiety disorders in a clinical sample. *Depression and Anxiety*, 22, 103–113.
- Gross, C., & Hen, R. (2004). The developmental origins of anxiety. *Nature Reviews Neuroscience*, 5, 545–552.
- Guyer, A. E., Masten, C. L., & Pine, D. S. (2013). Neurobiology of pediatric anxiety disorders. In R. A. Vasa & A. K. Roy (Eds.), *Pediatric anxiety disorders* (pp. 23–46). New York, NY: Springer.
- Hadwin, J. A., & A. P. Field (Eds.). (2010). *Information processing biases and anxiety: A developmental perspective*. Chichester, UK: John Wiley & Sons.
- Hakamata, Y., Lissek, S., Bar-Haim, Y., Britton, J. C., Fox, N. A., Leibenluft, E., . . . Pine, D. S. (2010). Attention bias modification treatment: A meta-analysis toward the establishment of novel treatment for anxiety. *Biological Psychiatry*, 68, 982–990.
- Harmon-Jones, E., Gable, P. A., & Peterson, C. K. (2010). The role of asymmetric frontal cortical activity in emotion-related phenomena: A review and update. *Biological Psychology*, 84, 451–462.
- Harrewijn, A., Van der Molen, M. J. W., & Westenberg, P. M. (2016). Putative EEG measures of social anxiety: Comparing frontal alpha asymmetry and delta–beta cross-frequency correlation. *Cognitive, Affective, & Behavioral Neuroscience*, 16, 1086–1098.
- Hastings, P. D., Kahle, S., & Nuselovici, J. M. (2014). How well socially wary preschoolers fare over time depends on their parasympathetic regulation and socialization. *Child Development*, 85, 1586–1600.
- Henderson, H. A., Fox, N. A., & Rubin, K. H. (2001). Temperamental contributions to social behavior: The moderating roles of frontal EEG asymmetry and gender. *Journal of the American Academy of Child & Adolescent Psychiatry*, 40, 68–74.

- Hoehl, S., & Striano, T. (2008). Neural processing of eye gaze and threat-related emotional facial expressions in infancy. *Child Development*, 79, 1752–1760.
- In-Albon, T., & Schneider, S. (2010). Using eye tracking-methodology in children with anxiety disorders. In J. A. Hadwin & A. P. Field (Eds.), *Information processing biases and anxiety: A developmental perspective* (pp. 129–149). Chichester, UK: Wiley-Blackwell.
- Kagan, J., Snidman, N., McManis, M., & Woodward, S. (2001). Temperamental contributions to the affect family of anxiety. *Psychiatric Clinics*, 24, 677–688.
- Kilpatrick, L. A., Zald, D. H., Pardo, J. V., & Cahill, L. F. (2006). Sex-related differences in amygdala functional connectivity during resting conditions. *Neuroimage*, 30, 452–461.
- Kindt, M., Bierman, D., & Brosschot, J. F. (1997). Cognitive bias in spider fear and control children: Assessment of emotional interference by a card format and a single-trial format of the Stroop task. *Journal of Experimental Child Psychology*, 66(2), 163–179.
- Kindt, M., Brosschot, J. F., & Everaerd, W. (1997). Cognitive processing bias of children in a real life stress situation and a neutral situation. *Journal of Experimental Child Psychology*, 64, 79–97.
- Kindt, M., Van Den Hout, M., De Jong, P., & Hoekzema, B. (2000). Cognitive bias for pictorial and linguistic threat cues in children. *Journal of Psychopathology and Behavioral Assessment*, 22, 201–219.
- Koster, E. H., Crombez, G., Verschuere, B., & De Houwer, J. (2004). Selective attention to threat in the dot probe paradigm: Differentiating vigilance and difficulty to disengage. *Behaviour Research and Therapy*, 42, 1183–1192.
- Kotsoni, E., de Haan, M., & Johnson, M. H. (2001). Categorical perception of facial expressions by 7-month-old infants. *Perception*, 30, 1115–1125.
- Last, C. G., Perrin, S., Hersen, M., & Kazdin, A. E. (1996). A prospective study of childhood anxiety disorders. *Journal of the American Academy of Child & Adolescent Psychiatry*, 35, 1502–1510.
- Lazarov, A., Marom, S., Yahalom, N., Pine, D. S., Hermesh, H., & Bar-Haim, Y. (2018). Attention bias modification augments cognitive-behavioral group therapy for social anxiety disorder: A randomized controlled trial. *Psychological Medicine*, 48, 2177–2185.
- Leppänen, J. M., & Nelson, C. A. (2006). The development and neural bases of facial emotion recognition. *Advances in Child Development and Behavior*, 34, 207–246.
- Leppänen, J. M., & Nelson, C. A. (2009). Tuning the developing brain to social signals of emotions. *Nature Reviews. Neuroscience*, 10, 37.
- Lewinsohn, P. M., Gotlib, I. H., Lewinsohn, M., Seeley, J. R., & Allen, N. B. (1998). Gender differences in anxiety disorders and anxiety symptoms in adolescents. *Journal of Abnormal Psychology*, 107, 109.
- Licht, C. M., De Geus, E. J., Van Dyck, R., & Penninx, B. W. (2009). Association between anxiety disorders and heart rate variability in The Netherlands Study of Depression and Anxiety (NESDA). *Psychosomatic Medicine*, 71, 508–518.
- LoBue, V. (2009). More than just another face in the crowd: Superior detection of threatening facial expressions in children and adults. *Developmental Science*, 12, 305–313.
- LoBue, V. (2013). What are we so afraid of? How early attention shapes our most common fears. *Child Development Perspectives*, 7, 38–42.
- LoBue, V., Buss, K. A., Taber-Thomas, B. C., Pérez-Edgar, K., & (2017). Developmental differences in infants' attention to social and nonsocial threats. *Infancy*, 22, 403–415.
- LoBue, V., & DeLoache, J. S. (2008). Detecting the snake in the grass: Attention to fear-relevant stimuli by adults and young children. *Psychological Science*, 19, 284–289.
- LoBue, V., & DeLoache, J. S. (2010). Superior detection of threat-relevant stimuli in infancy. *Developmental Science*, 13, 221–228.
- LoBue, V., & Pérez-Edgar, K. (2014). Sensitivity to social and non-social threats in temperamentally shy children at-risk for anxiety. *Developmental Science*, 17, 239–247.
- LoBue, V., & Rakison, D. H. (2013). What we fear most: A developmental advantage for threat-relevant stimuli. *Developmental Review*, 33, 285–303.
- LoBue, V., Rakison, D. H., & DeLoache, J. S. (2010). Threat perception across the life span: Evidence for multiple converging pathways. *Current Directions in Psychological Science*, 19, 375–379.
- MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin*, 109, 163.
- MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology*, 95, 15.
- MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., & Holker, L. (2002). Selective attention and emotional vulnerability: Assessing the causal basis of their association through the experimental manipulation of attentional bias. *Journal of Abnormal Psychology*, 111, 107.
- Mathews, A., & MacLeod, C. (1985). Selective processing of threat cues in anxiety states. *Behaviour Research and Therapy*, 23, 563–569.

- Mathews, A., & MacLeod, C. (2002). Induced processing biases have causal effects on anxiety. *Cognition & Emotion*, 16, 331–354.
- McGee, R. O. B., Feehan, M., Williams, S., Partridge, F., Silva, P. A., & Kelly, J. (1990). DSM-III disorders in a large sample of adolescents. *Journal of the American Academy of Child & Adolescent Psychiatry*, 29, 611–619.
- McLean, C. P., Asnaani, A., Litz, B. T., & Hofmann, S. G. (2011). Gender differences in anxiety disorders: Prevalence, course of illness, comorbidity and burden of illness. *Journal of Psychiatric Research*, 45, 1027–1035.
- Mineka, S., & Oehlberg, K. (2008). The relevance of recent developments in classical conditioning to understanding the etiology and maintenance of anxiety disorders. *Acta Psychologica*, 127, 567–580.
- Mogg, K., & Bradley, B. P. (1999). Orienting of attention to threatening facial expressions presented under conditions of restricted awareness. *Cognition & Emotion*, 13, 713–740.
- Mogg, K., Bradley, B. P., De Bono, J., & Painter, M. (1997). Time course of attentional bias for threat information in non-clinical anxiety. *Behaviour Research and Therapy*, 35, 297–303.
- Morales, S., Fu, X., & Pérez-Edgar, K. E. (2016). A developmental neuroscience perspective on affect-biased attention. *Developmental Cognitive Neuroscience*, 21, 26–41.
- Morales, S., Pérez-Edgar, K., & Buss, K. A. (2015). Attention biases towards and away from threat mark the relation between early dysregulated fear and the later emergence of social withdrawal. *Journal of Abnormal Child Psychology*, 43, 1067–1078.
- Morales, S., Taber-Thomas, B. C., & Pérez-Edgar, K. E. (2017). Patterns of attention to threat across tasks in behaviorally inhibited children at risk for anxiety. *Developmental Science*, 20, e12391.
- Morren, M., Kindt, M., van den Hout, M., & van Kasteren, H. (2003). Anxiety and the processing of threat in children: Further examination of the cognitive inhibition hypothesis. *Behaviour Change*, 20, 131–142.
- Naim, R., Kivity, Y., Bar-Haim, Y., & Huppert, J. D. (2018). Attention and interpretation bias modification treatment for social anxiety disorder: A randomized clinical trial of efficacy and synergy. *Journal of Behavior Therapy and Experimental Psychiatry*, 59, 19–30.
- Nelson, C. A., & Dolgin, K. G. (1985). The generalized discrimination of facial expressions by seven-month-old infants. *Child Development*, 56, 58–61.
- Nozadi, S. S., Troller-Renfree, S., White, L. K., Frenkel, T., Degnan, K. A., Bar-Haim, Y., ... Fox, N. A. (2016). The moderating role of attention biases in understanding the link between behavioral inhibition and anxiety. *Journal of Experimental Psychopathology*, 7, 451–465.
- Oakes, L. M. (2010). Infancy guidelines for publishing eye-tracking data. *Infancy*, 15, 1–5.
- Oakes, L. M. (2012). Advances in eye-tracking in infancy research. *Infancy*, 17, 1–8.
- Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General*, 130, 466.
- Öhman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: toward an evolved module of fear and fear learning. *Psychological Review*, 108, 483.
- Orvaschel, H., Lewinsohn, P. M., & Seeley, J. R. (1995). Continuity of psychopathology in a community sample of adolescents. *Journal of the American Academy of Child & Adolescent Psychiatry*, 34, 1525–1535.
- Peltola, M., Forssman, L., Puura, K., Leppänen, J., Biro, S., Huffmeijer, R., ... van IJzendoorn, M. (2015). Threat-related attentional biases at 7 months: Associations with later attachment security. SRCD Biennial Meeting, Philadelphia, USA.
- Peltola, M. J., Hietanen, J. K., Forssman, L., & Leppänen, J. M. (2013). The emergence and stability of the attentional bias to fearful faces in infancy. *Infancy*, 18, 905–926.
- Peltola, M. J., Leppänen, J. M., Palokangas, T., & Hietanen, J. K. (2008). Fearful faces modulate looking duration and attention disengagement in 7-month-old infants. *Developmental Science*, 11, 60–68.
- Peltola, M. J., Leppänen, J. M., Vogel-Farley, V. K., Hietanen, J. K., & Nelson, C. A. (2009). Fearful faces but not fearful eyes alone delay attention disengagement in 7-month-old infants. *Emotion*, 9, 560.
- Peltola, M. J., Yrttiaho, S., & Leppänen, J. M. (2018). Infants' attention bias to faces as an early marker of social development. *Developmental Science*, 21, e12687.
- Pérez-Edgar, K., Bar-Haim, Y., McDermott, J. M., Chronis-Tuscano, A., Pine, D. S., & Fox, N. A. (2010). Attention biases to threat and behavioral inhibition in early childhood shape adolescent social withdrawal. *Emotion*, 10, 349.
- Pérez-Edgar, K., & Fox, N. A. (2005). A behavioral and electrophysiological study of children's selective attention under neutral and affective conditions. *Journal of Cognition & Development*, 6, 89–116.
- Pérez-Edgar, K., & Guyer, A. E. (2014). Behavioral inhibition: Temperament or prodrome? *Current Behavioral Neuroscience Reports*, 1, 182–190.
- Pérez-Edgar, K., & Hastings, P. D. (2018). Emotion development from an experimental and individual differences

- lens. In J. T. Wixted (Ed.), *The Stevens' handbook of experimental psychology and cognitive neuroscience* (Vol. 4, 4th ed., pp. 289–321). New York, NY: Wiley.
- Pérez-Edgar, K., Kujawa, A., Nelson, S. K., Cole, C., & Zapp, D. J. (2013). The relation between electroencephalogram asymmetry and attention biases to threat at baseline and under stress. *Brain & Cognition*, 82, 337–343.
- Pérez-Edgar, K., McDermott, J. N. M., Korelitz, K., Degnan, K. A., Curby, T. W., Pine, D. S., & Fox, N. A. (2010). Patterns of sustained attention in infancy shape the developmental trajectory of social behavior from toddlerhood through adolescence. *Developmental Psychology*, 46, 1723.
- Pérez-Edgar, K., Morales, S., LoBue, V., Taber-Thomas, B. C., Allen, E. K., Brown, K. M., & Buss, K. A. (2017). The impact of negative affect on attention patterns to threat across the first two years of life. *Developmental Psychology*, 53, 2219–2232.
- Pérez-Edgar, K., Reeb-Sutherland, B. C., McDermott, J. M., White, L. K., Henderson, H. A., Degnan, K. A., . . . Fox, N. A. (2011). Attention biases to threat link behavioral inhibition to social withdrawal over time in very young children. *Journal of Abnormal Child Psychology*, 39, 885–895.
- Pérez-Edgar, K., Roberson-Nay, R., Hardin, M. G., Poeth, K., Guyer, A. E., Nelson, E. E., . . . Ernst, M. (2007). Attention alters neural responses to evocative faces in behaviorally inhibited adolescents. *Neuroimage*, 35, 1538–1546.
- Pérez-Edgar, K., Taber-Thomas, B., Auday, E., & Morales, S. (2014). Temperament and attention as core mechanisms in the early emergence of anxiety. In K. Lagattuta (Ed.), *Children and emotion* (Vol. 26, pp. 42–56). Basel, Switzerland: Karger Publishers.
- Pergamin-Hight, L., Naim, R., Bakermans-Kranenburg, M. J., van IJzendoorn, M. H., & Bar-Haim, Y. (2015). Content specificity of attention bias to threat in anxiety disorders: A meta-analysis. *Clinical Psychology Review*, 35, 10–18.
- Pigott, T. A. (1999). Gender differences in the epidemiology and treatment of anxiety disorders. *The Journal of Clinical Psychiatry*, 60, 4–15.
- Pine, D. S. (2007). Research review: A neuroscience framework for pediatric anxiety disorders. *Journal of Child Psychology and Psychiatry*, 48, 631–648.
- Pine, D. S., Cohen, P., Gurley, D., Brook, J., & Ma, Y. (1998). The risk for early-adulthood anxiety and depressive disorders in adolescents with anxiety and depressive disorders. *Archives of General Psychiatry*, 55, 56–64.
- Pine, D. S., Helfinstein, S. M., Bar-Haim, Y., Nelson, E., & Fox, N. A. (2009). Challenges in developing novel treatments for childhood disorders: Lessons from research on anxiety. *Neuropsychopharmacology: Official Publication of the American College of Neuropsychopharmacology*, 34, 213.
- Pine, D. S., Mogg, K., Bradley, B. P., Montgomery, L., Monk, C. S., McClure, E., . . . Kaufman, J. (2005). Attention bias to threat in maltreated children: Implications for vulnerability to stress-related psychopathology. *American Journal of Psychiatry*, 162, 291–296.
- Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32, 3–25.
- Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology*, 58, 1–23.
- Posner, M. I., Rothbart, M. K., Sheese, B. E., & Voelker, P. (2012). Control networks and neuromodulators of early development. *Developmental Psychology*, 48, 827.
- Pollak, S. D., & Kistler, D. J. (2002). Early experience is associated with the development of categorical representations for facial expressions of emotion. *Proceedings of the National Academy of Sciences*, 99, 9072–9076.
- Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology*, 74, 116–143.
- Price, R. B., Kuckertz, J. M., Siegle, G. J., Ladouceur, C. D., Silk, J. S., Ryan, N. D., . . . Amir, N. (2015). Empirical recommendations for improving the stability of the dot-probe task in clinical research. *Psychological Assessment*, 27, 365–376.
- Price, R. B., Siegle, G. J., Silk, J. S., Ladouceur, C. D., McFarland, A., Dahl, R. E., & Ryan, N. D. (2014). Looking under the hood of the dot-probe task: An fMRI study in anxious youth. *Depression and Anxiety*, 31, 178–187.
- Price, R. B., Wallace, M., Kuckertz, J. M., Amir, N., Gaur, S., Cummings, L., . . . Bar-Haim, Y. (2016). Pooled patient-level meta-analysis of children and adults completing a computer-based anxiety intervention targeting attentional bias. *Clinical Psychology Review*, 50, 37–49.
- Prior, M., Smart, D., Sanson, A., & Oberklaid, F. (2000). Does shy-inhibited temperament in childhood lead to anxiety problems in adolescence? *Journal of the American Academy of Child & Adolescent Psychiatry*, 39, 461–468.
- Rakison, D. H., & Derringer, J. (2008). Do infants possess an evolved spider-detection mechanism? *Cognition*, 107, 381–393.
- Rapee, R. M., & Heimberg, R. G. (1997). A cognitive-behavioral model of anxiety in social phobia. *Behaviour Research and Therapy*, 35, 741–756.

- Rinck, M., Reinecke, A., Ellwart, T., Heuer, K., & Becker, E. S. (2005). Speeded detection and increased distraction in fear of spiders: Evidence from eye movements. *Journal of Abnormal Psychology, 114*, 235.
- Rothbart, M. K., Posner, M. I., & Rosicky, J. (1994). Orienting in normal and pathological development. *Development and Psychopathology, 6*, 635–652.
- Rothbart, M. K., & Rueda, M. R. (2005). The development of effortful control. In U. Mayr, E. Awh, & S. Keele (Eds.), *Developing individuality in the human brain: A tribute to Michael I. Posner* (pp. 167–188). Washington, DC: American Psychological Association.
- Rothbart, M. K., Sheese, B. E., Rueda, M. R., & Posner, M. I. (2011). Developing mechanisms of self-regulation in early life. *Emotion Review, 3*, 207–213.
- Roy, A. K., Vasa, R. A., Bruck, M., Mogg, K., Bradley, B. P., & Sweeney, M., . . . CAMS Team. (2008). Attention bias toward threat in pediatric anxiety disorders. *Journal of the American Academy of Child & Adolescent Psychiatry, 47*, 1189–1196.
- Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2005). The development of executive attention: Contributions to the emergence of self-regulation. *Developmental Neuropsychology, 28*, 573–594.
- Ruff, H. A., & Rothbart, M. K. (2001). *Attention in early development: Themes and variations*. New York, NY: Oxford University Press.
- Salemink, E., van den Hout, M. A., & Kindt, M. (2007). Selective attention and threat: Quick orienting versus slow disengagement and two versions of the dot probe task. *Behaviour Research and Therapy, 45*, 607–615.
- Sass, S. M., Heller, W., Stewart, J. L., Siltan, R. L., Edgar, J. C., Fisher, J. E., & Miller, G. A. (2010). Time course of attentional bias in anxiety: Emotion and gender specificity. *Psychophysiology, 47*, 247–259.
- Scerif, G. (2010). Attention trajectories, mechanisms and outcomes: At the interface between developing cognition and environment. *Developmental Science, 13*, 805–812.
- Schmidt, N. B., Richey, J. A., Buckner, J. D., & Timpano, K. R. (2009). Attention training for generalized social anxiety disorder. *Journal of Abnormal Psychology, 118*, 5.
- Shechner, T., Britton, J. C., Pérez-Edgar, K., Bar-Haim, Y., Ernst, M., Fox, N. A., . . . Pine, D. S. (2012). Attention biases, anxiety, and development: Toward or away from threats or rewards? *Depression and Anxiety, 29*, 282–294.
- Sheese, B. E., Rothbart, M. K., Posner, M. I., White, L. K., & Fraundorf, S. H. (2008). Executive attention and self-regulation in infancy. *Infant Behavior and Development, 31*, 501–510.
- Striano, T., Kopp, F., Grossmann, T., & Reid, V. M. (2006). Eye contact influences neural processing of emotional expressions in 4-month-old infants. *Social Cognitive and Affective Neuroscience, 1*, 87–94.
- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643.
- Stuijzand, S., Creswell, C., Field, A. P., Pearcey, S., & Dodd, H. (2018). Research review: Is anxiety associated with negative interpretations of ambiguity in children and adolescents? A systematic review and meta-analysis. *Journal of Child Psychology and Psychiatry, 59*, 1127–1142.
- Taber-Thomas, B., et al. (In Press). Intrinsic functional correlates of frontal EEG asymmetry in developmental risk for psychopathology.
- Teller, D. Y. (1979). The forced-choice preferential looking procedure: A psychophysical technique for use with human infants. *Infant Behavior and Development, 2*, 135–153.
- Todd, R. M., Cunningham, W. A., Anderson, A. K., & Thompson, E. (2012). Affect-biased attention as emotion regulation. *Trends in Cognitive Sciences, 16*, 365–372.
- Vallorani, A., Fu, X., Morales, S., LoBue, V., Buss, K. A., & Pérez-Edgar, K. (under review). Person-centered profiles of infant affect-biased attention are associated with maternal anxiety and infant negative affect. *Emotion*.
- Vallorani, A., Thai, N., MacNeill, L., Morales, S., Taber-Thomas, B. C., & Pérez-Edgar, K. (under review). Combined risk: Temperamental, cognitive, and electrophysiological markers for social anxiety symptoms. *Journal of Abnormal Child Psychology*.
- Von Bockstaele, B., Verschuere, B., Tibboel, H., De Houwer, J., Crombez, G., & Koster, E. H. (2014). A review of current evidence for the causal impact of attentional bias on fear and anxiety. *Psychological Bulletin, 140*, 682.
- Wald, I., Shechner, T., Bitton, S., Holoshitz, Y., Charney, D. S., Muller, D., . . . Bar-Haim, Y. (2011). Attention bias away from threat during life threatening danger predicts PTSD symptoms at one-year follow-up. *Depression and Anxiety, 28*, 406–411.
- Waters, A. M., Bradley, B. P., & Mogg, K. (2014). Biased attention to threat in paediatric anxiety disorders (generalized anxiety disorder, social phobia, specific phobia, separation anxiety disorder) as a function of ‘distress’ versus ‘fear’ diagnostic categorization. *Psychological Medicine, 44*, 607–616.
- Waters, A. M., Henry, J., Mogg, K., Bradley, B. P., & Pine, D. S. (2010). Attentional bias towards angry faces in

- childhood anxiety disorders. *Journal of Behavior Therapy and Experimental Psychiatry*, 41, 158–164.
- Waters, A. M., Lipp, O. V., & Spence, S. H. (2004). Attentional bias toward fear-related stimuli: An investigation with nonselected children and adults and children with anxiety disorders. *Journal of Experimental Child Psychology*, 89, 320–337.
- Waters, A. M., Mogg, K., Bradley, B. P., & Pine, D. S. (2008). Attentional bias for emotional faces in children with generalized anxiety disorder. *Journal of the American Academy of Child & Adolescent Psychiatry*, 47, 435–442.
- Whalen, P. J. (1998). Fear, vigilance, and ambiguity: Initial neuroimaging studies of the human amygdala. *Current Directions in Psychological Science*, 7, 177–188.
- White, L. K., Degnan, K. A., Henderson, H. A., Pérez-Edgar, K., Walker, O. L., Shechner, T., . . . Fox, N. A. (2017). Developmental relations among behavioral inhibition, anxiety, and attention biases to threat and positive information. *Child Development*, 88, 141–155.
- White, L. K., McDermott, J. M., Degnan, K. A., Henderson, H. A., & Fox, N. A. (2011). Behavioral inhibition and anxiety: The moderating roles of inhibitory control and attention shifting. *Journal of Abnormal Child Psychology*, 39, 735–747.
- White, L. K., Sequeira, S., Britton, J. C., Brotman, M. A., Gold, A. L., Berman, E., . . . Leibenluft, E. (2017). Complementary features of attention bias modification therapy and cognitive-behavioral therapy in pediatric anxiety disorders. *American Journal of Psychiatry*, 174, 775–784.
- Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin*, 120, 3.
- Yiend, J. (2010). The effects of emotion on attention: A review of attentional processing of emotional information. *Cognition and Emotion*, 24, 3–47.

Author biographies

Jessica L. Burris, PhD, is a Postdoctoral Researcher at Rutgers University under the mentorship for Dr. Vanessa LoBue. Her research program investigates the interactions between attention to and neural processing of emotion, and environmental factors in populations at risk for atypical development.

Kristin Buss, PhD is Professor of Psychology and Human Development and Family Studies at The Pennsylvania State University. Her research focuses on emotional and temperament development with particular focus on fear reactivity and regulation and risk for anxiety-related trajectories from infancy to adolescence.

Vanessa LoBue, PhD, is an Associate Professor of Psychology at Rutgers University, Newark. Dr. LoBue directs the Child Study Center and her research program investigates human behavioral responses to emotionally valenced stimuli—specifically to negative or threatening stimuli—and the mechanisms guiding the development of these responses.

Koraly Pérez-Edgar, PhD, is the McCourtney Professor of Child Studies and a Professor of Psychology at The Pennsylvania State University. Dr. Pérez-Edgar's research focuses on the relations between temperament and psychopathology. In particular, she examines how individual differences in attention can work to ameliorate or exacerbate risks associated with early temperament traits.

Andy P. Field is Professor of Quantitative Methods at The University of Sussex. He research focuses broadly on the development of emotional responses in young children including the role of temperament, family, and social environments. He also devotes a lot of his energy to statistics education within and beyond the social sciences.